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TO ASK A QUESTION, ONE MUST KNOW ENOUGH TO KNOW WHAT IS NOT KNOWN

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Is some appropriate level of prior knowledge a prerequisite for asking questions about a new topic matter? The hypothesis that learners should ask the most questions when their knowledge is well matched to the level of presentation was tested using two levels of background knowledge and two levels of difficulty of material to-be-learned. Subjects said aloud their questions and thoughts while learning. Novice learners asked more questions on the easier material than learners with some training; trained learners asked more questions than novices on the harder material. Accordingly, theories of question asking in learning should address interactions between knowledge levels of askers and material.

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To Ask a Question, One Must Know Enough to Know What is Not Known

Naomi Miyake and Donald A. Norman

To ask a question of someone implies more than a need for information. It also implies a proper structure of knowledge with which to formulate the question and to interpret the response. Thus, the ability of a person to think of an appropriate question on a topic matter is a complex function of the knowledge of that topic.

At a research seminar on computer techniques, we noted that beginners at programming (to whom the seminar was addressed) asked few questions and generated few comments. More expert programmers, however, had many questions and, eventually, dominated the discussion. Reflection on this observation indicated that a general principle might be involved: in order to be able to ask questions about new material, one's knowledge of the topic must be at an appropriate level: the number of questions should be an inverted U-shaped function of the relationship between student knowledge and task complexity.

Consider the novice exposed to expert level material: although there should be many difficulties in understanding, the novice does not even have the proper framework within which to ask questions. Thus, although at first glance, one might expect novices to be filled with questions, there are strong theoretical reasons not to expect this.

Consider the expert exposed to novice material. Here, there should be good structural framework for the material on the part of the expert,

but a lack of questions: there are no gaps or inconsistencies in the knowledge that need to be filled. The maximum number of questions should occur when a person is well matched to the level of presentation. There should be sufficient background knowledge, but the new material should indeed be new, with inconsistencies or incomplete information that causes the learner to question the interpretation, to seek more information, or to confirm the existing understanding.

The ability to ask questions during the learning of new material, therefore, seems to be a function of two variables: the existence of appropriate knowledge structures, and the level of completeness of those structures with respect to the new material. When there are two presentation levels of the same material, easy and hard, the learner with the ample knowledge structure should ask more questions on the harder presentation and less on the easier one; the learner with little knowledge should ask most questions with the easier presentation and not many with the harder presentation.

Considerable research has been done on question answering, but we have been unable to find relevant experimental or theoretical studies on the generation of questions. Some relevant issues are discussed in the speech-act literature, but the relevance is indirect. Grosz (Note 1) and Levin and Moore (1977) have looked at a naturalistic dialogue situations, but they did not perform any analyses relevant to the issues being raised here.

This paper tests the predicted interaction. The topic to be learned is a computer text editor. This is a topic for which it is easy

to find subjects with no prior knowledge. Thus, it is relatively easy to manipulate the amount of prior knowledge, as well as the difficulty level of the material.

Method

Design

We used two levels of background knowledge and two levels of difficulty of the material to be learned. Subjects were preselected to have little or no prior knowledge about text editors or computers. *Trained* subjects received a pre-experimental training session. Other subjects (*novices*) did not. There were two levels of the learning task: the level called *Easy* was quite less advanced than the level called *Hard*.

There were four groups of subjects, with 15 subjects per group: trained, Easy; trained, Hard; novice, Easy; novice, Hard. The order of the conditions were:

1. training (for subjects in trained conditions only);
2. a practice task;
3. a baseline task;
4. the learning task.

Training

During the training session, subjects learned a task related to the final learning task. Using a simplified training manual, the subjects in the two "trained" groups learned three commands of the text editor called ED: how to print, how to delete, and how to add a line of text.

After practicing these three commands on the computer terminal, the subjects were given three new texts, each of which had mistakes marked: they were asked to fix the mistakes. They could refer back to the training manual. During the training, the experimenter was available for help, but no more information than that given in the training manual was provided. The amount of training was selected to be sufficient for subjects to gain a sense of the text editor. The training session took some 25 to 50 minutes, depending on the ability of each subject. All the trained subjects reached the level where they could fix at least one text out of three without any help.

The practice and baseline tasks

The goal of the experiment was to collect freely occurring thoughts and questions of the subjects who were learning different levels of materials. Accordingly, it was felt important to train the subjects in giving protocols naturally. (It takes a little bit of training to speak thoughts and questions aloud freely, especially when the thoughts are not responded to.) In addition, because different subjects would have different baseline rates of asking questions and speaking, we wished to get a calibration of their baseline rate.

All the materials for the practice, baseline, and learning tasks were presented on individual index cards, held in a loose-leaf binder. Each card had one or two sentences. Subjects read each card and were instructed to say their thoughts and questions aloud.

The practice material was three sentences taken from an article in a popular science magazine (Mahoney, 1978). Each sentence was on a

separate index card. After each subject finished reading and responding to the third sentence, all the quesquestions up to that point were answered by the experimenter. There was only one subject who did not say anything, and so he was given the two most common questions and their answers as examples.

The baseline task was to learn to play Owari, an African board and counter game, quite different from most board games in the United States. The explanation was made deliberately obscure. It consisted of six very short paragraphs (only one or two sentences each), each on a separate index card. Subjects' questions were again answered at the end of this session. (All subjects asked questions in the baseline task.)

The learning task

Two versions of the instructional manual for the text editor NED were constructed. The *Easy Manual* was readable for people with no experience with computers; it used only non-technical language, gave detailed explanation for concepts, and taught five commands by first presenting concrete examples and later more abstract explanations. The *Hard Manual* was more technical, written for experienced readers. It taught seven commands and three special characters. It presented abstract conceptual explanations first, followed by a specification of how to do each command. Both the Easy and Hard Manuals were divided into 30 steps, each of which consisted of one or two sentences, each step on a separate index card. (NED differs from ED, the editor used in the training. The instruction manual used for ED was considerably different from either of the manuals used in the learning task for NED.)

During the learning task, subjects were asked to read the material page by page and to say aloud all the questions and thoughts which came to mind. The instructions were specifically aimed at making the task natural. All the utterances were tape recorded. In order to keep the amount of information available the same from subject to subject, the experimenter never responded to these questions.

Subjects

Sixty undergraduates in introductory psychology courses at the University of California, San Diego served as subjects, either for course credits or pay. They were pre-selected to have no knowledge of either text editors or computers. It was hoped that no subjects would be familiar with the base line task, Owari. However, 12 subjects recognized the game while reading the explanation. They were disqualified and replaced with new subjects.

Results

Coding of Transcripts

All the protocols recorded during the baseline and learning tasks were transcribed. There does not yet exist an adequate method for analyzing naturally occuring questions. Considerable syntactic and semantic variations were observed in these studies. Accordingly, we first devised a rough classification of the utterances into ten different categories. It was difficult to make unambiguous classifications of all the questions into these ten categories, however, and so these categories were grouped into four composite, more conceptual categories

(plus a fifth category, looking back). Four of the transcripts, one from each experimental group, were randomly selected and coded by an independent judge and the results were compared with the codings by one of the authors (N.M.). Between coder reliability was only about 0.7 on the ten categories, but was 0.95 on the composite classifications. Examples of the questions and the categorizations used are shown in Table 1. Only the five categories are considered in this paper. They are:

1. Overall questions: The total number of questions, including repetitions, paraphrases of previously asked questions, and marginal questions (an interrogative, but with no substantial content).

2. Number of concepts: The number of concepts for which further clarification was asked. Operationally, this is the total number of questions, minus repetitions, paraphrases and marginal questions.

3. Hypotheses: The number of specific hypotheses or subjects' own interpretations--a measure of how easily subjects could speculate about the possible answers to their own questions.

The composite categories "number of concepts" and "hypotheses" are both subsets of the composite category "overall questions": moreover, the two overlap in sharing some common subcategories.

4. Confirmations: The number of utterances (other than questions) in which subjects stated their own interpretation of the material. Mere reading aloud was not included. This category reflects subjects' understanding of the material, but with an apparent need for confirmation of the interpretation.

Table 1

Coding Categories, Example statements, and Composite Categories.

(In parentheses are shown previously asked questions.)

Categories	Example statements
Questions	
With contents	
Original	
With hypotheses	"Is NED a person?"
Without hypotheses	"What does NED stand for?"
Paraphrased	
With hypotheses	"(Is NED a person?) Or a computer?"
Without hypotheses	"(What is the commnad?) What type of thing do you want to type in, that would be considered as command?"
Repeated	"(What is the buffer?) Again, what is the buffer?"
Without contents	"What...?"
Judgements	"I am confused."
Confirmations	"Oh, so insert goes backward, instead of forward like append does."
Verbatim reading aloud	

Composite Categories:

Overall questions = All statements categorized as "Questions" above.

Number of concepts = All statements categorized as "Questions - With contents - Original" above.

Hypotheses = "Questions - With contents - Original - With hypotheses" + "Questions - With contents - Paraphrased - With hypotheses."

Confirmations = All statements categorized as "Confirmations" above.

5. Look-backs: The total number of the times subjects turned back to previous pages. The number of pages turned back was not counted. (The data were recorded by the experimenter during the baseline and learning tasks.)

Adjustment for tendency to ask questions

There were considerable individual differences in the tendency to speak aloud. To compensate for this propensity to speak, the number of utterances in the experimental condition was adjusted by using the number of questions observed in the baseline condition. The argument for this adjustment is simple. In the baseline condition, all subjects were novices. Therefore, differences in the number of questions could only result from individual differences in speaking styles. Moreover, there were no significant differences in mean baseline frequency among the four experimental groups. The correlation between overall questions in the baseline condition and overall questions in the learning task was .66. The regression equation for the number of overall questions was:

$$TQ = 6.2 + 1.7\ BQ,$$

where TQ is the learning task questions and BQ is the baseline questions. Accordingly, the slope of the regression equation was used to determine the adjustment factor: the number of overall questions, number of concepts, and hypotheses were divided by 1.7BQ. All statistical analyses were done on both raw scores and adjusted scores, and both values will be reported. (We used the slope of the regression equation for our

The mean number of overall baseline questions was 4.7 for the novice subjects with the Easy Manual, 4.9 for the trained subjects with the Easy Manual, 7.2 for the novice subjects with the Hard Manual, 5.5 for the trained subjects with the Hard Manual.

correction because it provided a satisfactory and easy estimate. Note, however, that our results are not sensitive to the form of the adjustment used. The primary point of the paper is confirmed by using the raw data, without adjustment. Performing the adjustment does allow some secondary results to reach significance.)

The number of "confirmations" and "look-backs" were not adjusted because the baseline frequencies for more than 40 subjects were zero (this is about 2/3 of the subjects). Moreover, the correlation between the baseline and the learning phase for these two categories was low ($r = .23$ and $.38$, for confirmations and look-backs respectively).

Findings

The results for questions confirm expectations. All the adjusted questioning scores show significant interactions between the training conditions and the levels of the instructional manuals: with the easier manual, novice subjects asked more questions than trained; with the harder manual, trained subjects asked more questions than novices. Figure 1 shows the pattern based on the number of concepts, the most rigid, qualitative measure of questioning. The F values for the interactions calculated from the 2 X 2 analysis of variance (training conditions by manual levels) are, $F\ (1, 56) = 32.34$, $p < .01$ for overall questions; $F\ (1, 56) = 32.35$, $p < .01$ for the number of concepts; $F\ (1, 56) = 6.59$, $p < .05$ for hypotheses. [1]

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1. Main effects were not significant, except for training conditions on overall questions ($F\ (1, 56) = 6.93$, $p < .05$) and on concepts ($F\ (1, 56) = 4.47$, $p < .05$). Main effects themselves do not convey much information, because the experimental hypotheses clearly call for the significant interactions.

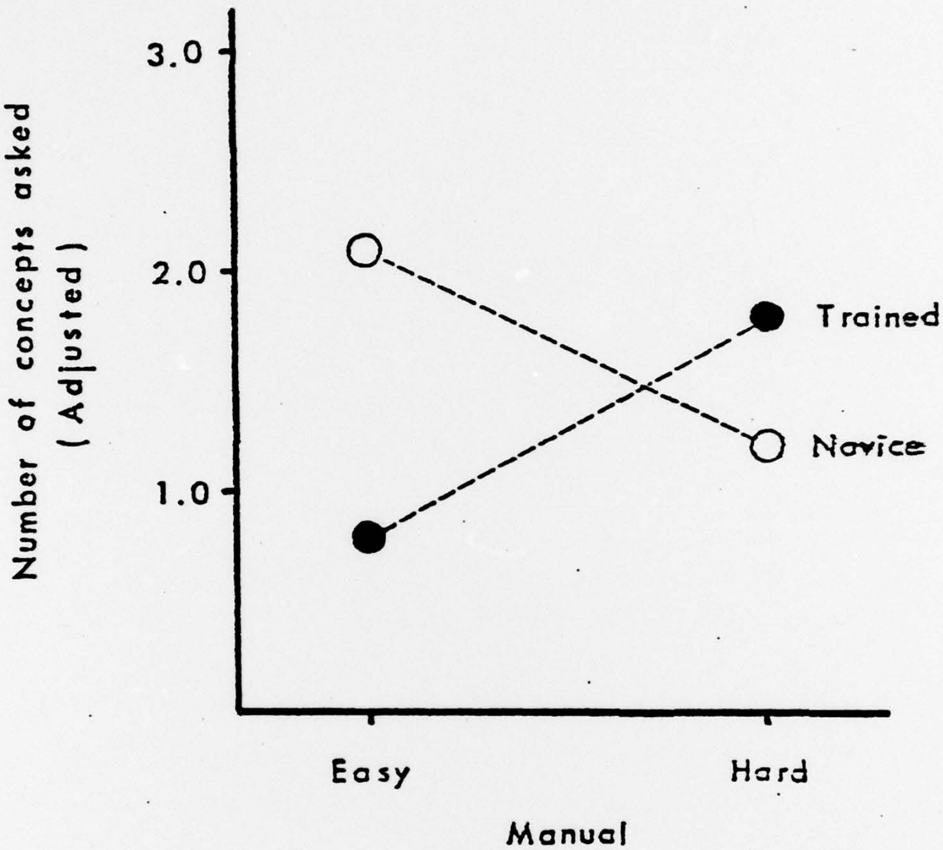

Figure 1. Interactional pattern of adjusted scores for number of concepts asked during learning task.

The mean questioning scores (both raw and adjusted) are shown in Table 2. With the exception of the hypotheses, all the raw frequencies show the interacting pattern in the predicted order. The *F* values for the interactions are $F\ (1,\ 56) = 12.39$, $p < .01$ for overall questions; $F\ (1,\ 56) = 11.72$, $p < .01$ for the number of concepts; $F\ (1,\ 56) = 1.90$, for hypotheses. [2]

Simple main effects for the factor of manual levels are mostly significant. All the questioning scores on the Easy Manual are significantly greater for novices than for trained subjects. The *F* values are $F\ (1,\ 56) = 34.81$, $p < .01$ for overall questions; $F\ (1,\ 56) = 30.50$, $p < .01$ for concepts; $F\ (1,\ 56) = 13.76$, $p < .01$ for hypotheses. On the Hard Manual, where the question is whether the trained subjects asked more questions than the novices, only the category of hypotheses fails to reach the significant level difference. The *F* values for overall questions, concepts, and hypotheses are $F\ (1,\ 56) = 4.70$, $p < .05$; $F\ (1,\ 56) = 6.39$, $p < .05$; and $F\ (1,\ 56) = 0.45$, respectively.

Mean number of confirmations and look-backs are shown in Figure 2 and Table 3 (these are raw, unadjusted data). Although the interaction of confirmation does not reach significance, ($F\ (1,\ 56) = 2.22$), the data do show the appropriate pattern of interaction. Look-backs have a unique pattern, with neither significant interaction ($F\ (1,\ 56) = 0.30$), nor any significant differences between the novices and the trained subjects. The Hard Manual elicits more look-backs than the Easy Manual (main *F* for manual levels is $F\ (1,\ 56) = 4.92$, $p < .05$).

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2. Only one main effect, the training condition factor on overall questions ($F\ (1,\ 56) = 5.44$, $p < .05$) is significant.

Table 2

Mean Number of Questions Asked

While Learning the Easy Manual or the Hard Manual.

(Standard deviations are given in parentheses.)

	Easy Manual		Hard Manual	
	Novice	Trained	Novice	Trained
Raw frequencies				
Overall	20.9	6.5	16.2	19.1
	(11.9)	(4.5)	(10.1)	(10.1)
Concepts	15.1	5.9	12.5	15.3
	(7.3)	(3.9)	(7.6)	(7.6)
Hypotheses	7.0	1.5	7.5	7.2
	(7.5)	(1.7)	(9.1)	(8.5)
Adjusted scores				
Overall	2.8	0.9	1.5	2.2
	(1.2)	(0.7)	(0.5)	(0.9)
Concepts	2.1	0.8	1.1	1.8
	(0.8)	(0.6)	(0.4)	(0.7)
Hypotheses	0.9	0.2	0.6	0.7
	(0.9)	(0.2)	(0.3)	(0.8)

Table 3

Mean Number of Confirmations and Look-backs.

(Standard deviations are given in parentheses.)

	Easy Manual		Hard Manual	
	Novice	Trained	Novice	Trained
Confirmations	2.5	1.3	1.0	2.9
	(4.5)	(2.4)	(2.1)	(6.0)
Look-backs	1.3	1.7	2.7	3.9
	(1.3)	(2.2)	(1.9)	(5.3)

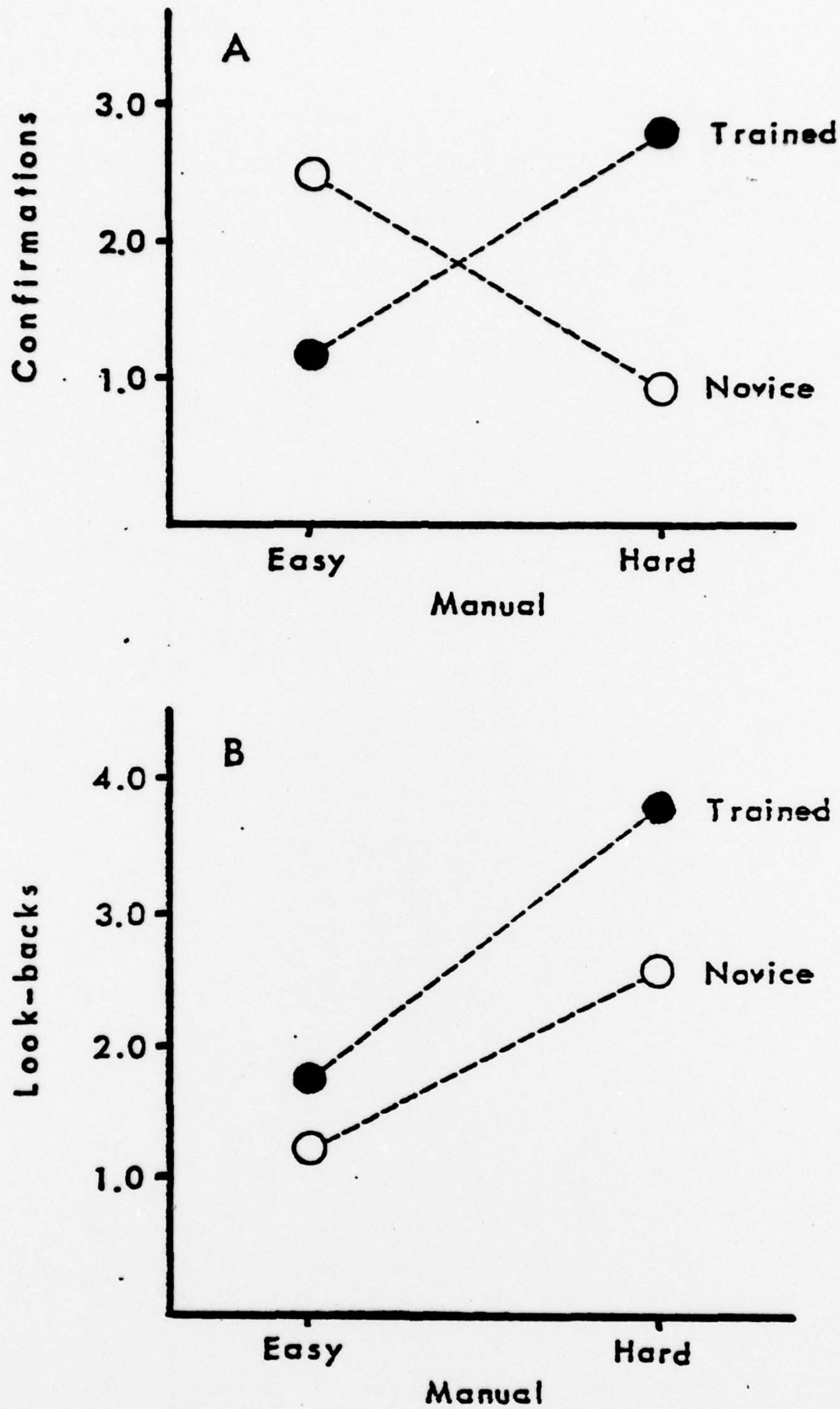

Figure 2. Interactional patterns of confirmations and look-backs. A: Confirmations. B: Look-backs.

Discussion

The most interesting result is that novices do not ask many questions on material that is too difficult. This finding shows that a theory of questioning that suggests that people ask questions to fill in their knowledge structures is too simplistic. People do not appear to be able to cope with material too far beyond their present knowledge.

The number of overall questions gives a quantitative measure of the general tendency to ask questions. The number of concepts and hypotheses can be viewed as reflecting more qualitative aspects of questioning. To ask about a concept, the subjects must know what is missing and what is necessary for further understanding; questions asking about concepts thus imply the asker is at an appropriate distance from the given material. To create a hypothesis, subjects should have some expectation or inferred understanding beyond the given material; hypotheses thus imply the asker is active in constructing a knowledge structure. In this sense, the novices who learned on the easier manual and the trained subjects on the harder manual had the greater tendency to ask questions, not only quantitatively but qualitatively.

Because the two instructional manuals differed in structural properties, it is possible to infer what subjects in each group were doing. The Easy Manual first presented concrete examples and later, more abstract explanations; the Hard Manual presented the abstract concepts first and then, later, the detailed specification of how to use each command.

The novices given the Easy Manual started without knowledge of the text editor task, but the manual provided concrete examples which could be used as the "core" to start learning. Thus, these subjects could follow the manual, constantly expanding the scope of their knowledge.

The novices on the Hard Manual also started without any specific knowledge, but had to cope immediately with the abstract framework. It was as if they did not know what they should know to know further. By the time they came to more concrete examples, it was too late.

Look-backs can be regarded either as a measure of the complexity of the material or as a measure of memory loss. There should be more memory loss for the novices on the Hard Manual, because they had the greatest trouble in following the material. Similarly, trained subjects on the Hard Manual should need to check back on the materials, because they were taking in the largest amount of information. These two types of look-backs are indistinguishable with the present data. The data for look-backs are consistent with either interpretation. However, the relatively high score of the novices with the Hard Manual implies that they were actually trying to understand the material, not just flipping the page with boredom; they simply did not know what they should ask.

This paper is one of the first experimental attempts to manipulate question asking in a learning task. The results show that at least some aspects of complex learning are accessible through the measures of question asking. The results also show that any theory of question asking in learning cannot simply use the gaps in a person's knowledge as the source of questions. To ask a question, knowing too little is just as disadvantageous as knowing too much.

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